

REMARKS

The Examiner is thanked for the due consideration given the application and for the withdrawal of the restriction requirement.

Claims 55-79 remain in the application. Independent claims 55 and 72 have been amended to better set forth the claimed invention. More specifically, the claims clarify that the pre-made aerosol catalyst particles can be obtained only by one of two ways and no other, either by i) physical vapor nucleation of catalyst material or ii) by solution droplet thermal decomposition of catalyst precursor.

Although it is believed that there is no change to the claim scope, the background of the instant claims can be found in the specification at page 3, lines 24-26, page 5, lines 20-21 and in Figure 1 and claim 1 of the originally filed application (WO 2005/085130).

No new matter is believed to be added to the application by this amendment.

Entry of this amendment is respectfully requested because it raises no new issues and places the application in condition for allowance.

Rejection Under 35 USC §112, Second Paragraph

Claims 55-79 have been rejected under 35 USC §112, second paragraph as being indefinite. This rejection is respectfully traversed.

The Office Action asserts that claims 55 and 72 set forth pre-made catalyst particles that presents a "chicken-or-egg" scenario as to when this material is produced.

However, the claims have been amended to clarify and to better denote that the catalyst particles are obtained before the reaction to produce the nanotubes, for example by the "providing" language of claim 55. Claim 72 has also been clarified to better indicate that the device for producing the catalyst is separate from the reactor(s) producing the nanotubes.

As a result, the Office cannot take the position that example *"a substrate supported catalyst particles used for carbon nanotube synthesis"* is included in the scope of the amended claim (claim 55 clearly presents that the catalyst particles are in aerosol form (not substrate-supported) when they are introduced into the reactor).

That is, claim 55 has been amended in order to make the claim more clear in this aspect. The first step of the method is to produce catalyst particles by physical vapor nucleation of catalyst material or by solution droplet thermal decomposition of catalyst precursor, and the second step of the method is to introduce these pre-made catalyst particles, which are in aerosol

form (due to their production method), and to react these pre-made aerosol catalyst particles with one or more carbon sources introduced into the reactor such that carbon nanotubes are formed.

The claims are thus clear, definite and have full antecedent basis.

This rejection is believed to be overcome, and withdrawal thereof is respectfully requested.

Rejections Based On Kamalakaran

Claims 55-59, 63-67, 70, 72-73, 75-76 and 79 have been rejected under 35 U.S.C. §102(b) as being anticipated by Kamalakaran, *Synthesis of thick and crystalline nanotube arrays by spray pyrolysis*, Applied Physics Letters 2000; 77(21): 3385-3387 in view of Zhang, et al., *Rapid growth of well-aligned carbon nanotube arrays*, Chemical Physics Letters 2002; 362: 285-290 to show a state of fact.

Claim 68 has been rejected under 35 U.S.C. §103(a) as obvious over Kamalakaran in view of ZHANG et al., and further in view of Maruyama, et al., *Low-temperature synthesis of high-purity single-walled carbon nanotubes from alcohol*, Chemical Physics Letters 2002; 360: 229-334.

Claim 69 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Kamalakaran in view of Zhang et al., and further in view of (i) Thostenson, *Advances in the science and technology of carbon nanotubes and their composites: a review*,

Composite Science and Technology 2001; 61: 1899-1912, (ii) Lavin et al. (U.S. Patent 6,426,134) and (iii) Pienkowski et al. (U.S. Patent 6,599,961).

Claim 71 has been rejected under 35 U.S.C. §103(a) as obvious over Kamalakaran in view of ZHANG et al., and further in view of Vivekchand, et al., *Carbon nanotubes by nebulized spray pyrolysis*, Chemical Physics Letters 2004; 386: 313-318.

These rejections are respectfully traversed.

The present invention pertains to producing carbon nanotubes from a gas phase utilizing pre-made aerosol catalyst particles. A reactor that can be used to produce these nanotubes is depicted in Figure 3(a) of the application, which is reproduced below.

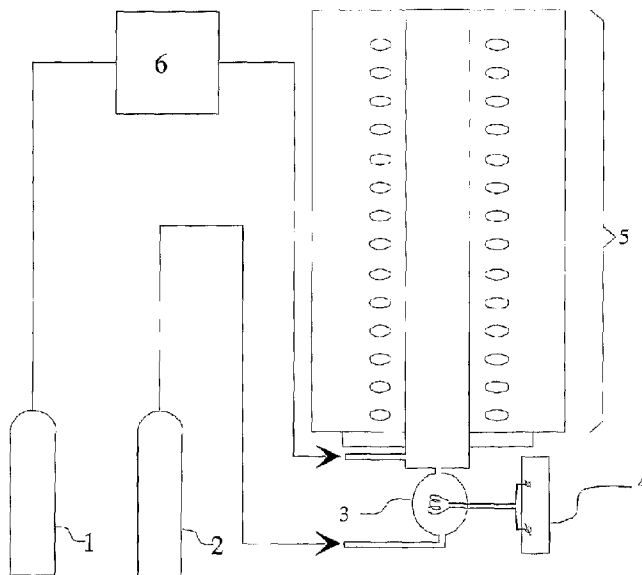


Figure 3(a)

As is set forth in independent claim 55, the nanotubes may be formed by "*providing pre-made aerosol catalyst particles,*

said pre-made aerosol catalyst particles having been produced by a method selected from the group consisting of physical vapor nucleation of catalyst material or by and solution droplet thermal decomposition of catalyst precursor; introducing said pre-made aerosol catalyst particles into a reactor; introducing one or more carbon sources into the reactor; and reacting said pre-made aerosol catalyst particles and said one or more carbon sources in the reactor to produce carbon nanotubes." See also apparatus claim 72.

As has been noted in the previous amendment, Kamalakaran does not disclose or in any way suggest the separate production of pre-made aerosol catalyst particles and the synthesis of carbon nanotubes in accordance with the present invention.

On the contrary, Kamalakaran discloses the production of catalyst particles simultaneously with the carbon nanotubes synthesis. Therefore, Kamalakaran does not in any way disclose or suggest the formation of catalyst particles beforehand, separately from the carbon nanotube synthesis.

The Office has rejected the observations presented in the previous amendment in relation to Kamalakaran, asserting that Kamalakaran does not set forth separate production of catalyst particles and synthesis of carbon nanotubes using the pre-made catalyst particles. The Office has asserted that even in

Kamalakaran catalyst particles are produced before the carbon nanotubes are synthesized.

In Kamalakaran, the catalyst precursor material is introduced in a cold solution (benzene, i.e., the carbon source), which is sprayed on the walls of the reactor, i.e., the solution is deposited on the reactor wall where aligned or unaligned carbon nanotube growth takes place. This is a **supported CVD process**, not a gas phase method as in accordance with amended claim 55.

Only wall supported CVD processes are able to produce such carpet-like morphologies. In the method according to the present invention the carbon nanotubes are formed in the gas phase not on the wall of the reactor.

In conclusion, the process of Kamalakaran is totally different from the present invention.

This can also be seen from the product produced by the method of Kamalakaran. With the method of Kamalakaran carbon fibers and/or multi-walled nanotubes with a diameter of 30 to 200 nm are produced. With the method of the present invention single (or at most double or triple walled) carbon nanotubes are produced.

Further, the diameter of the single-walled carbon nanotubes produced with the method in accordance with the present invention is below 2 nm. Therefore, the method in accordance with

instant claim 55 (and 72) is new and inventive in view of Kamalakaran.

The other applied art does not address at least the deficiencies of Kamalakaran discussed above.

Kamalakaran alone or in combination thus does not anticipate or render *prima facie* obvious independent claims 55 and 72 of the present invention. Claims depending upon claims 55 or 72 are patentable for at least these reasons.

These rejections are believed to be overcome, and withdrawal thereof is respectfully requested.

Rejections Based On Dillon et al.

Claims 55-59, 63-68, 70, 72-76 and 79 have been rejected under 35 U.S.C. §102(b/e/a) as being anticipated by WO 03/056078 to Dillon, et al. (U.S. Publication 2004/0265211 A1) in view of Zhang et al.

Claim 69 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Dillon et al. in view of Zhang et al., and further in view of (i) Thostenson, (ii) Lavin et al. (U.S. Patent 6,426,134) and (iii) Pienkowski et al.

Claim 71 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Dillon et al. in view of Zhang et al., and further in view of Vivekchand, et al., *Carbon nanotubes by nebulized spray pyrolysis*, Chemical Physics Letters 2004; 386: 313-318.

As has been noted in the previous amendment, in the method of Dillon et al., no actual catalyst particles are used to synthesize nanotubes. Dillon et al. only disclose the use of vaporized catalyst material. Further, Dillon et al. do not disclose the separate production of pre-made catalyst particles and formation/synthesis of carbon nanotubes in accordance with the present invention.

Dillon et al. do disclose the formation of catalyst material in the presence of carbon precursor material in the same place (process chamber) where the synthesis, i.e., the formation, of carbon nanotubes takes place. That is, the catalyst precursor will dissociate at the same time/place as the carbon nanotubes nucleate.

In contrast, in instant claim 55 (and 72), it is clear that the present invention provides the separate production of catalyst particles, i.e., their production in absence of a carbon source or at conditions, where carbon nanotube nucleation does not occur, and then the use of such pre-made aerosol catalyst particles in a reactor together with one or more carbon sources for the synthesis of carbon nanotubes.

Consequently, the separate control of catalyst generation and carbon nanotube nucleation and growth results in better control of the individual process steps, and thus better control of the product.

In the example of Dillon et al., the hot wire is used primarily to heat the process chamber. Moreover, according to Dillon it may be fabricated from any material able to achieve the required process temperatures (between 1500 and 2500 °C). In the method according to the present invention, much lower process temperatures are achievable since the hot wire serves only to generate catalyst materials and is not used as a primary heat source for the reactor. This represents an unexpected result over Dillon.

Dillon et al. alone or in combination thus do not anticipate or render *prima facie* obvious independent claims 55 and 72 of the present invention. Claims depending upon claims 55 or 72 are patentable for at least these reasons.

These rejections are believed to be overcome, and withdrawal thereof is respectfully requested.

Rejections Based On Simard et al.

Claims 55-61, 63-68, 70, 72-73, 75-77 and 79 have been rejected under 35 U.S.C. §102(b) as being anticipated by WO 02/076887 to Simard et al.

Claims 69 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Simard et al., and further in view of (i) Thostenson, (ii) Lavin et al. (U.S. Patent 6,426,134) and (iii) Pienkowski et al.

These rejections are respectfully traversed.

Simard et al. disclose the formation of nanoparticles of metal catalyst via laser ablation and aerosolization and the growth of nanotubes. The features of Simard et al. are not included in the instant independent method claim and the instant independent apparatus claim of the present invention since the closed wording of these claims exclude this interpretation.

In contrast to the present invention, Simard et al. teach the production of catalyst particles in the presence of a carbon source. In Simard et al., the process entails laser ablation of a bulk metal catalyst within a hydrocarbon solution to produce a feedstock containing metal catalyst nanoparticles. This feature is excluded from the amended claim set.

Further, according to the present invention the catalyst particles are produced in the absence of a carbon source or in conditions that carbon nanotubes do not grow so that catalyst and nanotube synthesis can be separately controlled.

Additionally, Simard et al. do not form catalyst particles by physical vapor nucleation of catalyst material or by solution droplet thermal decomposition of catalyst precursor in accordance with the present invention.

Also, the independent claims of the present invention have been instantly rewritten so as to exclude reading in an "*aerosolisation step*".

Simard et al. alone or in combination thus does not anticipate or render *prima facie* obvious independent claims 55

and 72 of the present invention. Claims depending upon claims 55 or 72 are patentable for at least these reasons.

These rejections are believed to be overcome, and withdrawal thereof is respectfully requested.

Rejections Based On Sato et al.

Claims 55-66, 70, 72-73, 75-76 and 79 have been rejected under 35 U.S.C. 102(b/a) as being anticipated by Sato et al., *Growth of diameter-controlled carbon nanotubes using monodisperse nickel nanoparticles obtained with a differential mobility analyzer*, Chemical Physics Letters 2003; 382: 361-366.

Claims 71 and 77-78 are rejected under 35 U.S.C. 103(a) as being unpatentable over Sato, et al.

Claims 66-68 have been rejected under 35 U.S.C. §103(a) as obvious Sato et al. in view of Maruyama, et al.

Claim 69 has been rejected under 35 U.S.C. §103(a) as being unpatentable over Sato et al., and further in view of (i) Thostenson, (ii) Lavin et al. (U.S. Patent 6,426,134) and (iii) Pienkowski et al.

These rejections are respectfully traversed.

Sato et al. disclose the generation of nanoparticles by laser ablation, i.e., the production of pre-made catalyst particles. The pre-made catalyst particles are size classified after which they are deposited onto a substrate. Then the substrate with the pre-made catalyst particles, i.e., the nickel

particles, is transferred to a CVD chamber, where the growth of carbon nanotubes takes place.

Sato et al. do not disclose a gas phase method for the production of carbon nanotubes using pre-made aerosol catalyst particles and one or more carbon sources during the formation/synthesis of carbon nanotubes in accordance with instant method claim 55 and instant apparatus claim 72.

It should be strongly emphasized that Sato et al. do not produce catalyst particles using a method such that the produced catalyst particles would be in aerosol form when they are introduced into a reactor, where the carbon nanotube synthesis takes place in accordance with the present invention.

Further, Sato et al. do not disclose a method, where the carbon nanotubes are produced from a gas phase using catalyst particles being in aerosol form. Instead in the method of Sato et al. the catalyst particles are formed on a substrate, which is then introduced into a reactor where the carbon nanotubes are synthesised on the substrate, i.e., the catalyst particles are not in aerosol form when introduced into a reactor but are substrate-supported and further the carbon nanotubes are not formed from a gas phase but are produced by a substrate-supported growth.

That is, Sato et al. disclose the production of carbon nanotubes on a substrate, where the catalyst particles are

deposited. This is not an aerosol method in accordance with the present invention.

Further, there is no suggestion or teaching in Sato et al. that would lead a person skilled in the art to the present invention, where carbon nanotubes are formed from a gas phase using pre-made aerosol catalyst particles and one or more carbon sources.

Sato et al. alone or in combination thus does not anticipate or render *prima facie* obvious independent claims 55 and 72 of the present invention. Claims depending upon claims 55 or 72 are patentable for at least these reasons.

These rejections are believed to be overcome, and withdrawal thereof is respectfully requested.

Summary of the Present Invention and the Applied Art

The advantage of the present invention where the catalyst particles are produced as a separate step and where these pre-made catalyst particles are introduced into the reactor, where the carbon nanotube synthesis takes place, after they have been formed, is that with the present invention uniformly sized catalyst particles can be produced and correspondingly the size of the carbon nanotubes can be accurately controlled. When catalyst particles with controlled size and uniformity are introduced into a reactor and used for the synthesis of carbon nanotubes, the produced carbon nanotubes will also be uniform.

This is a desired property of the produced carbon nanotubes, which allows the end users of the carbon nanotubes to produce high quality products.

The separate production of catalyst particles and of carbon nanotubes enables the separate control of these two separate process steps and thus their separate optimizing. As the catalyst particles are separately produced in time it is also possible to classify the produced catalyst particles if needed before they are used in the carbon nanotube synthesis.

In comparison, the cited publications do not disclose a method in the sense of claim 55 or an apparatus of claim 72. The cited publications do not disclose the present invention where catalyst particles are produced by physical vapor nucleation of catalyst material or by solution droplet thermal decomposition of catalyst precursor, and where these pre-made aerosol catalyst particles are introduced into a reactor, where they are used with one or more carbon sources introduced into the reactor to produce carbon nanotubes.

Thus, the subject matters of claims 55 and 72 are patentable. Claims depending upon claims 55 or 72 are patentable for at least the above reasons.

Request For Interview

If this amendment does not place the application in condition for allowance, the Examiner is respectfully requested

to contact the Applicant's representative at the telephone number below to arrange a telephonic interview.

Conclusion

The Examiner is thanked for considering the Information Disclosure Statements filed December 8, 2006 and September 8, 2006, and for making the references therein of record in the application.

Prior art of record but not utilized is believed to be non-pertinent to the instant claims.

As no issues remain, the issuance of a Notice of Allowability is respectfully solicited.

The Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 25-0120 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17.

Respectfully submitted,

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